FINAL
2015 EOD RANGE ASSESSMENT REPORT
Vandenberg Air Force Base, California

Contract Number GS10F0059N
Delivery Order Number FA8903-15-F-0023

Prepared for:

Department of the Air Force
1028 Iceland Avenue
30 CES/CEIEC
Vandenberg Air Force Base, California

U.S. AIR FORCE

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05 AUGUST 2016

FINAL

CERTIFICATION

for

2015 EOD RANGE ASSESSMENT REPORT

RCRA PART B TREATMENT FACILITY

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2,4-DNT	2,4-Dinitrotoluene
2,4,6-TNT	2,4,6-Trinitrotoluene
AFB	Air Force Base
ANFO	ammonium nitrate and fuel oil
bgs	below ground surface
bTOC	below top of well casing
BTV	background threshold value
Cal EPA	California Environmental Protection Agency
CAM	California Assessment Manual
CHHSL	California Human Health Screening Level
CCR	California Code of Regulations
DO	dissolved oxygen
DoD	Department of Defense
DRMO	Defense Reutilization and Marketing Office
DTSC	Department of Toxic Substances and Control (California)
DU	Decision Unit
ELAP	Environmental Laboratory Accreditation Program
EOD	Explosive Ordnance Disposal
GPS	global positioning system
IRP	Installation Restoration Program
ITRC	Interstate Technology & Regulatory Council
kg	kilogram
lbs	pounds
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MI	multi-incremental
MIS	multi-incremental sampling
mV	millivolt
NTU	Nephelometric Turbidity Unit
ORP	oxidation/reduction potential
PEP	propellant, explosive, and pyrotechnic
PPE	personal protective equipment
RCRA	Resource Conservation and Recovery Act
RDX	cyclotrimethylenetrinitramine
RSL	regional screening levels
SAP	Sampling and Analysis Plan
SVOC	semivolatile organic compound

Tetra Tech	Tetra Tech, Inc.
TOC	total organic compound
TPH	total petroleum hydrocarbons
TPHd	diesel-range total petroleum hydrocarbons
TPHe	extractable-range total petroleum hydrocarbons
TPHmo	heavy hydrocarbon-range total petroleum hydrocarbons
U.S. EPA	United States Environmental Protection Agency
VOC	volatile organic compound

1.0 INTRODUCTION

This report summarizes the activities and findings of the 2015 annual sampling and analysis of the Vandenberg Air Force Base (AFB), Resource Conservation and Recovery Act (RCRA) Part B Treatment Facility, Explosive Ordnance Disposal (EOD) Range. This work is conducted annually to assess potential environmental impacts to soil and groundwater resulting from disposal operations of propellant, explosive, and pyrotechnic (PEP) materials at the EOD Range to comply with permit conditions set forth in Part B of the Vandenberg AFB Hazardous Waste Facility Permit (DTSC 2008). This report evaluates the extent to which disposal of PEP materials may lead to explosives residues, perchlorate, and metals accumulating in surface soil, shallow subsurface soil, and groundwater of the site. The field investigation portion of this work was conducted from 14 December 2015 to 16 December 2015 in accordance with the approved Sampling and Analysis Plan (SAP) dated July 2008 (Tetra Tech, Inc. [Tetra Tech] 2008).

1.1 Site Description

The EOD Range, located at Vandenberg AFB (Figure 1), is defined by a 2,500-foot radius, circular boundary centered on a point approximately 1 mile west of the intersection of Mira and Tangair Roads and 300 feet south of Mira Road (Figure 2). The majority of this area is designated as a buffer zone for safety considerations, while the active portion of the range (detonation area) consists of a graded area, which is several hundred feet in diameter and largely free of vegetation. A cylindrical metal bunker, with earth piled up on the south side, is located adjacent to Mira Road near the north edge of the detonation area. The active portion of the range is re-graded two to three times a year.

The EOD Range is primarily located on Burton Mesa; an area of Vandenberg AFB comprised of a series of marine terraces that were formed during the Middle to Late Pleistocene Epoch (10,000 to 900,000 years ago). No drainage channels or other evidence of surface water runoff are present in the immediate vicinity of the graded area. Cañada Tortuga Creek and a small tributary are present within the 2,500-foot-radius EOD Range but are well outside the graded, active area. Surface soils in the area are loose sands, with large portions of the graded area soils also having light to strong cementation in the upper few inches that have been exposed by grading. Rainwater likely infiltrates before runoff develops. Groundwater is present beneath only a portion of the site in a restricted perched zone that is evaluated annually at groundwater monitoring well EOD-MW-1. Groundwater has not been found during previous investigations elsewhere at the EOD Range (Tetra Tech 2000).

1.2 EOD Range Operations

The EOD Range operations are regulated under the Vandenberg AFB RCRA Part B Permit. The Part B Permit authorizes the treatment of up to 500 pounds (lbs.) of PEP materials per day; however, the actual volume of material managed for treatment at the range has substantially decreased each year to de-minimus amounts. During CY2014 and CY2015, only five total disposal detonations occurred with a net explosive weight of 8.09 and 0.58 lbs. respectively. These detonations were used as EOD Flight training exercises. The EOD Range receives unused PEP materials for disposal in accordance with the RCRA permit. These materials include obsolete ordnance, explosive waste from training operations, materials with an expired shelf life, or World War II and Korean Conflict era explosive waste discovered in former firing range and maneuver areas on the base. The PEP materials are disposed of via open detonation at the Range, which has been used for this purpose since 1945. Detonations are conducted at the approximate center of the graded area (Figure 2).

Routine training detonations are conducted approximately once a month and as required by Air Force Instruction (AFI) with each detonation using approximately 33 lbs. of C-4 explosive. These detonations are conducted at ground level and sufficient explosive is used so that no visible trace of the items being destroyed remains after the detonation. The explosives are directed to force the explosion downward into the item being destroyed and into the ground. Generally, the only material thrown upward by the explosions is soil. These explosions create small craters in the ground, which are filled in during re-grading activities.

Until 2011, the EOD Range detonation area was also used by the Air Force to explode a simulated truck bomb twice a year (typically during May and October). The "truck bomb" detonations were conducted for training purposes in joint exercises that included Air Force and Federal law enforcement personnel. The training event was intended to simulate a crime scene where an improvised explosive device had been detonated. The truck bombs used a mixture of ammonium nitrate and fuel oil (ANFO) as the explosive. Trucks were obtained from the Defense Reutilization and Marketing Office (DRMO). The 30 Logistics Readiness Squadron drained all fluids and removed hazardous materials such as batteries prior to the detonation.. The EOD flight personnel then placed ANFO explosives in the vehicles and detonated them. After the training event, Air Force personnel gathered any remaining debris for disposal as scrap at the DRMO. The Air Force permanently discontinued truck bomb detonations after the final training event in fall 2010 (Almodovar 2012).

2.0 METHODOLOGY

2.1 Site Reconnaissance

Project personnel conducted site reconnaissance and interviews with staff from the 30th Civil Engineer Squadron and the EOD Flight (30 CES/CED) during development of the SAP (Tetra Tech 2008) to evaluate potential contaminant sources and transport routes, and to verify procedures at the EOD Range. During the 2015 sampling event, Mr. Nelson Almodovar of the EOD Flight was interviewed for updated range use information and for field work scheduling. Mr. Almodovar confirmed that, except for the discontinuation of the annual truck bomb training event, procedures have not changed since the SAP was prepared (Almodovar 2015). The following is a summary of information obtained from EOD Flight staff and observations made during 2015 field work.

The graded area is approximately 600 feet by 900 feet and is largely free of vegetation. A cylindrical metal bunker with earth piled up on the south side is located on the northeast margin of the graded area. The bunker was formerly used as shelter for EOD personnel during detonations; however, it does not conform with Air Force safety regulations (Technical Order 60A-1-1-22, General EOD Safety Precautions); therefore, it is no longer used. Small pieces of plastic and metal debris, ranging in size up to approximately 10 centimeters, are scattered widely across the graded area at a very low density (approximately one piece of debris per 900 to 1,200 square feet). During the site reconnaissance, a number of approximately 6-foot long and 1-foot diameter dummy bombs were observed arrayed near the bunker. These dummy bombs are inert, constructed of thick-walled steel and filled with concrete.

During the Site reconnaissance and sampling, personnel observed multiple detonation craters present in the primary detonation area of the range. Each crater was approximately 7 to 8 feet wide and between 4 and 5 feet deep.

2.2 Screening Values

Chemical concentrations evaluated annually in soil and ground-water at the EOD Range are compared to screening values in accordance with the SAP (Tetra Tech 2008). These screening values include the following:

- Vandenberg AFB background threshold values (BTVs) for metals in soil and groundwater;
- United States Environmental Protection Agency (U.S. EPA) regional screening levels (RSLs) (U.S. EPA May 2016);

- California Human Health Screening Level (CHHSL) for industrial soil (perchlorate only) (California Environmental Protection Agency [Cal EPA] 2010);

- California maximum contaminant levels (MCLs) for drinking water found in Title 22 of the California Code of Regulations (CCR), and

- Project-specific screening levels for extractable range TPH (TPHe) that define when analysis for VOCs and SVOCs is required.

The relevant BTVs, RSLs, MCLs, and project-specific screening levels are presented in Tables 1 through 6.

Several changes to the screening levels presented in the SAP (Tetra Tech 2008) have been adopted since approval by DTSC in 2008. The SAP identifies the California Department of Health Services notification level of 6 micrograms per liter (μg/L) for perchlorate in groundwater as an additional screening level; however, California replaced the notification level with an MCL of 6 μg/L in October 2007. Metals concentrations are compared to the 95th percentile BTVs for metals in soil and groundwater for Vandenberg AFB initially established in the *Basewide Background Sampling Report* (JEG 1994). However, several BTVs for soil and groundwater were updated in *Refined Background Threshold Values for Metals in Soil* (MWH 2009) and *Refined Background Threshold Values for Metals in Groundwater* (MWH 2010). Therefore, certain BTVs referenced to evaluate metals concentrations in the EOD Range Assessment report differ slightly from the values initially approved for screening in the SAP (Tetra Tech 2008). A table showing the BTV screening values presented in the SAP compared to the refined BTVs is presented in Appendix A of this report. The refined BTVs were accepted by the DTSC and Central Coast Regional Water Quality Control Board for the screening of metals in soils and groundwater under the Vandenberg AFB Installation Restoration Program (IRP) in letters dated 9 March 2010 and 8 June 2010, respectively. Therefore, results for surface soil samples collected from 0 to 6 inches below ground surface (bgs) are compared to the refined Burton Mesa surface alluvium BTVs and results for soil samples collected below 6 inches bgs are compared to the refined Burton Mesa subsurface alluvium BTVs. Filtered groundwater sample results are compared to the refined BTVs for Burton Mesa groundwater.

During the 2015 EOD Range assessment, groundwater sampling parameters were also conducted to evaluate the concentrations of total organic carbon (TOC), total nitrogen as nitrate and nitrite (total nitrogen), chloride, and sulfate to evaluate the site groundwater for perchlorate natural attenuation parameters. The concentrations of chloride and sulfate were compared to BTVs for groundwater. There are no BTVs established for Vandenberg AFB groundwater for total nitrogen or TOC.

2.3 Sampling Methodology

2.3.1 Groundwater

Monitoring well EOD-MW-1 was installed at the EOD Range in 2000, approximately 400 feet southwest of the detonation point (Figure 2). On 6 July 2009, a dedicated, low-flow bladder pump was installed. The pump has a 4-inch-long inlet, and was installed with the bottom of the inlet approximately 1 foot above the bottom of the well, which places the inlet within a perched groundwater zone within a sandy gravel (GW) horizon. The sandy gravel is in contact with impermeable Monterey Formation bedrock from between 9.5 and 14.5 feet bgs (Appendix B). The perched groundwater horizon is limited in areal extent and, as discussed in the SAP, other attempts to install additional monitoring wells within the Range footprint failed due to the absence of groundwater elsewhere at the EOD Range.

Monitoring well EOD-MW-1 was sampled on 15 December 2015 for this assessment (Section 2.4). The static water level in the well prior to purging was 8.62 feet below the top of the well casing (bTOC). The total depth of the well was measured at 14.2 feet bTOC; therefore, the total water column was 5.58 feet. As further detailed below, the well was purged between 0.1 and 0.2 liters per minute for approximately 120 minutes on 14 December 2016 and for 265 minutes on 15 December 2016. A total purge volume of approximately 38.6 liters was collected during the sampling event. During purging, the water level, temperature, conductivity, pH, turbidity, dissolved oxygen (DO), and oxidation/reduction potential (ORP) were measured every 5 minutes. EOD-MW-1 did not reach stabilization parameter goals for turbidity (10 NTUs), which caused a prolonged purging event over the two days. Due to time constraints while on the EOD range, purging was suspended on 14 December 2015 and resumed on 15 December 2016. The field crew encountered the same turbidity production on 15 December 2016; turbidity stabilized in the 60-70 NTU range. Because DO and conductivity remained stable, and are more reliable stabilization parameters than turbidity, the Vandenberg AFB Hazardous & Solid Waste Compliance Manager agreed that EOD-MW-1 could be sampled although turbidity was elevated. The water quality parameters measured during sampling are presented in Table 8 and on the purge record in Appendix C.

The groundwater sample collected on 15 December 2016 was analyzed for metals, perchlorate, explosives, TPHe, total nitrogen, chloride, sulfate, and TOC. In accordance with the SAP, sample aliquots were also collected for potential VOC and SVOC analysis to be held by the laboratory pending the results of the TPHe analysis. Two sample aliquots were submitted for metals analyses. One aliquot was filtered in the field with a 0.45-micron in-line filter to obtain metals concentrations that can be compared to the groundwater BTVs for Burton Mesa, which were developed based on field-filtered samples. The second aliquot was not filtered and was submitted for total metals analysis to assess exposure concentrations to potential receptors. The sample container submitted for perchlorate analysis was filled with ample headspace in order to minimize the possibility of anaerobic degradation.

2.3.2 Soil

Soil sampling at the EOD Range was conducted on 15 December 2015 and 16 December 2015 and consisted of surface and subsurface soil sampling. The SAP specifies EPA method SW8330B, using a multi-incremental sampling (MIS) approach, as the sampling and testing method for surface soil samples (Tetra Tech 2008). Multi-increment (MI) surface soil samples were collected within four delineated polygonal areas referred to as decision units (DUs) (Figure 3). Within each DU, field personnel walked a zig-zag path and collected 30 discrete aliquots from approximately equidistant sampling locations along the sampling path to make a single MI sample. MI surface soil samples were collected from DUs EOD-DU1, EOD-DU2, EOD-DU3, and EOD-DU4 (Figure 3). A field replicate sample was collected from EOD-DU4 and is identified as sample EOD-DU5.

MI surface soil samples were collected from a depth of 0 to 4 inches. Field observations indicate that the depth of grading is not more than 4 to 8 inches; therefore, surface soil samples collected from a depth of 0 to 4 inches are expected to be representative of the graded soil column. Aliquots for the MI samples were collected using dedicated disposable plastic spoons in order to prevent cross-contamination. Prior to sampling, a 35-gram aliquot of EOD Range soil was weighed on site and placed into the unmarked polyethylene measuring container. The resulting level was marked with permanent ink on the side of the container. The field crew observed that two full volumes of the disposable spoon resulted in equal volume and weight aliquots of 35g. Repeating this method of standard measure for the resulting MI sample ensured the desired final sample weight of slightly greater than 1 kilogram (kg) (30 aliquots times 35 grams equals 1,050 grams, or 1.05 kg). Each aliquot was collected using a new spoon dedicated to each DU, then transferred to a zip-lock plastic bag containing the other aliquots for the DU being sampled. Each zip-lock bag was weighed to ensure it weighed a minimum 1.05 kg.

The soil sample locations were selected based upon the estimated potential airborne contaminant transport. The primary lateral contaminant transport mechanism is likely the scattering of material into the air by the detonations and resulting downwind transport. The prevailing wind direction is from the northwest; therefore, the majority of sampling locations were located in a radial pattern on the southeast (downwind) side of the

EOD detonation area (Figure 3) (Tetra Tech 2008). EOD-DU1 encompassed the EOD detonation area. EOD-DU2 and EOD-DU3 were downwind from the EOD detonation area. EOD-DU4 was upwind of the detonation area and was included to detect potential contaminants that may have settled upwind or been deposited during times when the wind was blowing from the southeast, opposite to the prevailing wind direction.

In addition to the MI surface soil samples, discrete subsurface soil samples were collected from borings EOD-B1 through EOD-B10 using a hand auger with a stainless steel auger bucket as the sampling device (Figure 3). Using a Global Positioning System (GPS) hand-held unit, all of the discrete subsurface locations were re-acquired from past events. Subsurface borings EOD-B1 through EOD-B3 are located in the detonation area, within EOD-DU1. Subsurface borings EOD-B4 through EOD-B9 are located downwind of the detonation area, within EOD-DU2 and EOD-DU3. Subsurface boring EOD-B10 is located upwind of the detonation area, within EOD-DU4. Surface soils at the EOD range consist predominantly of silty sands, which are slightly to strongly cemented in some areas, and a clay or clayey sand horizon that is generally encountered at depths between 0.5 and 3 feet bgs. Representative boring logs showing sedimentary details are provided in Appendix B. Metals and organic compounds commonly sorb to clay particles and as a result, contaminants may be transported to the subsurface via rainwater percolation and concentrated in the first few inches of the clayey material. In all ten borings, the subsurface soil samples were collected at depths where the clayey material was first encountered, which ranged from 0.5 to 2.5 feet bgs. In addition, one replicate subsurface soil sample was collected from location EOD-B4 at 2.5 feet bgs. Also, discrete surface and subsurface samples were collected from the previous truck bomb sampling locations. Truck bomb detonations have not occurred since 2010.

Except for soil collected for VOC analysis, all discrete soil samples for this assessment were collected in 4-ounce glass jars, which were immediately placed into a cooler containing ice to chill the samples and minimize exposure to sunlight. Aliquots of soil for VOC analysis were collected directly into Encore™ containers and immediately placed on ice. Multi-increment samples, which comprised approximately a kilogram of soil, were collected in laboratory supplied, 1-gallon, re-closable, plastic bags, carried from one sample aliquot location to the next wrapped inside a black trash bag within a 5-gallon bucket to minimize exposure to sunlight. Once complete, the MI samples were double-bagged, and each was placed in the shipping cooler.

In addition to the samples described above, discrete surface and subsurface soil samples were collected from the truck bombing area to assess the potential presence of TPHe from truck bomb training operations. The borings from which these samples were collected are shown on Figure 3 and are labelled EOD-TB-1 through EOD-TB-6. A field duplicate sample was also collected from EOD-TB-6 at each discrete interval and was labelled EOD-TB-7. Discrete surface soil samples were collected from 0 to 0.5 foot bgs (labeled EOD-TB-X-0.0, where X is the boring number), and discrete subsurface soil samples were collected from the first depth at which clayey material was encountered or at 4 feet bgs. The subsurface samples are designated EOD-TB-X-D.D, where D.D is the depth in decimal feet. All of the discrete samples from the truck bombing area were submitted for TPHe analysis. Also, additional sample volumes were submitted for VOC and SVOC analysis and held. They would be analyzed in the event any of the TPHe results are greater than 1,000 milligrams per kilogram (mg/kg).

2.4 Sample Analyses

All samples were analyzed by TestAmerica St. Louis. TestAmerica is a Department of Defense (DoD) Environmental Laboratory Accreditation Program (ELAP)-certified and California ELAP-certified analytical testing laboratory. Chain-of-custody documentation is presented in Appendix D.

2.4.1 Groundwater

The groundwater sample collected from well EOD-MW-1 was analyzed for the following:

- Dissolved (filtered) and total (unfiltered) metals included in the 17 California Assessment Manual (CAM 17) list plus aluminum and iron using EPA methods SW6010B and SW7470A;
- Explosives via EPA Method SW8330B;
- Perchlorate via EPA Method SW314;
- TOC by EPA Method 9060;
- Total nitrogen as nitrate and nitrite by EPA Method 353.1;
- Chloride and sulfate by EPA Method E300;
- TPHe by EPA Method SW8015B;
- VOCs by EPA Method SW8260B, and
- SVOCs by EPA Method SW8270B.

The CAM 17 list metals include the heavy metals commonly associated with ordnance disposal and satisfy the requirements for characterizing the sampled media as hazardous or non-hazardous. In addition, the list includes all of the metals referenced in the EOD Waste Stream Inventory in the EOD Waste Analysis Plan (Vandenberg AFB 2004).

The addition of analytical methods for TOC, total nitrogen, chloride, and sulfate to the annual groundwater analytical program is in accordance with recommendations from DTSC included with the approval of the 2011 EOD Range Assessment Report (DTSC 2011). The methods were added to evaluate groundwater conditions for evidence of natural biological attenuation of perchlorate. The Interstate Technology & Regulatory Council (ITRC) has reported that groundwater geochemistry can influence the ability of naturally occurring species of bacteria to use perchlorate as an energy source (ITRC 2002, 2005, 2008).

The EOD-MW-1 groundwater sample was also analyzed for VOCs and SVOCs even though TPHe was not detected. A detailed explanation of this variance is provided below in Section 3.1.5.

2.4.2 Soil

Multi-increment surface soil samples collected from the DUs (EOD-DU1, EOD-DU2, EOD-DU3, and EOD-DU4) were analyzed for:

- CAM 17 metals, plus aluminum and iron via EPA methods SW6010B and SW7470A;
- Explosives via EPA Method 8321; and
- Perchlorate via EPA Method SW6850.

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Discrete subsurface soil samples collected from borings EOD-B1 through EOD-B10 were analyzed for:

- CAM 17 metals plus aluminum and iron via EPA methods SW6010B and SW7470A;
- Explosives via EPA Method SW8330B; and
- Perchlorate via EPA Method SW6850.

Discrete subsurface and surface soil samples collected from borings EOD-TB-1 through EOD-TB-6 were analyzed for:

- TPHe by 8015B;
- VOCs by 8260B for any samples exhibiting TPHe above 1,000 mg/kg; and
- SVOCs by 8270C for any samples exhibiting TPHe above 1,000 mg/kg.

2.5 Variances

The 2015 EOD Range sampling was performed in accordance with the DTSC approved SAP and approved modifications, presented as the scope of work in the Notification of Fieldwork letter submitted to DTSC on 17 November 2015.

As detailed below in Section 3.1.5, a variance from the laboratory method for TPHe occurred when the groundwater samples collected from EOD-MW-1 were not analyzed within the prescribed method hold time. Thus, the reporting limits were flagged as estimated values, and the additional contingent VOC and SVOC analyses were performed in order to be conservative and meet the intent of the SAP requirements. Furthermore, SVOC analyses on the groundwater samples were also analyzed one day out of the prescribed method hold time. Due to this fact SVOC reporting limits were flagged as estimated values.

3.0 RESULTS

Analytical results for groundwater are presented Tables 1, 2 and 3. Analytical results for soil are presented in Tables 4 and 5. Historical groundwater and soil concentrations of key chemicals of concern are summarized in Table 7. Historical groundwater geochemistry results are presented in Table 8. The chain-of-custody forms and laboratory report packages are provided in Appendices D and E, respectively. Results for dissolved (filtered) metals in groundwater are compared to the Vandenberg AFB BTVs for Burton Mesa (JEG 1994; MWH 2010). Results for total (unfiltered) metals, explosives, and perchlorate in groundwater are compared to the California Primary MCL for drinking water and the EPA RSLs for tap water (EPA 2016). Similarly, results for metals in soil samples are compared to the BTVs (JEG 1994; MWH 2009), and results for metals, explosives, and perchlorate in soil samples are compared to the EPA RSLs for industrial soil (EPA 2016).

In accordance with the SAP, the analytical data were subjected to a data validation review to evaluate data quality and verify that the data quality objectives presented in the SAP were met. The data validation is summarized in the Quality Assurance Report presented in Appendix E. Data validation showed that with appropriate qualifications, all data were usable for their intended purpose.

3.1 Groundwater

3.1.1 Metals

Aluminum, chromium, and iron were detected at concentrations above the applicable BTVs in the filtered groundwater sample collected from monitoring well EOD-MW-1 (Table 1). Aluminum was detected at an estimated value of 10,300 micrograms per liter (µg/L) in sample EOD-MW-1-1215 and 10,500 µg/L in the duplicate sample, EOD-MW-2-1215. These values are both greater than the BTV of 1,200 µg/L and the California MCL of 1,000 µg/L. Chromium was detected at a concentration of 17 µg/L in sample EOD-MW-1-1215 and 17.3 µg/L in EOD-MW-2-1215, which is greater than the BTV of 12 µg/L and below the California MCL of 50 µg/L. Iron was detected above its BTV of 3,530 µg/L at estimated concentrations of 11,800 µg/L in sample EOD-MW-1-1215 and 11,700 µg/L in sample EOD-MW-2-1215. Both of these values are below the California MCL of 14,000 µg/L for iron.

Arsenic was detected in the filtered groundwater samples at an estimated concentration of 5.22 µg/L in sample EOD-MW-1-1215 and 6.74 µg/L in sample EOD-MW-2-1215, above the RSL of 0.052 µg/L (Table 1). Arsenic was previously detected in unfiltered groundwater at concentrations above the RSL and MCL for tap water in 2009 and above the RSL in 2012 (Table 7).

Aluminum, chromium, and iron were detected at concentrations above the applicable BTV in the unfiltered groundwater sample collected from monitoring well EOD-MW-1 (Table 1). Aluminum was detected at an estimated value of 10,400 micrograms per liter (µg/L) in sample EOD-MW-1-1215 and 10,300 µg/L in sample EOD-MW-2-1215, which is greater than the BTV of 1,200 µg/L. Chromium was detected at a concentration of 16.8 µg/L in sample EOD-MW-1-1215 and 16.8 µg/L in EOD-MW-2-1215, which is greater than the BTV of 12 µg/L. Iron was detected at an estimated concentration of 11,800 µg/L in sample EOD-MW-1-1215 and an estimated concentration of 11,800 µg/L in sample EOD-MW-2-1215 compared to a BTV of 3,530 µg/L.

Arsenic was previously detected in unfiltered groundwater at concentrations above the RSL and MCL for tap water in 2009 and above the RSL in 2012 and 2013 (Table 7).

No other metals were detected at concentrations above project screening levels in the filtered and unfiltered groundwater samples.

3.1.2 Explosives

As during the previous EOD Range assessments, no explosives were detected in the groundwater sample collected from monitoring well EOD-MW-1 (Table 2, Table 7).

3.1.3 Perchlorate

Perchlorate was not detected in the groundwater sample collected from well EOD-MW-1 on 15 December 2015 (Table 2). Since 2009, perchlorate has been detected intermittently in site groundwater samples at concentrations ranging between 0.14 µg/L and 73 µg/L (Tables 7 and 8).

3.1.4 Common Anions and Total Organic Carbon

The unfiltered groundwater sample collected from EOD-MW-1 was also analyzed for chloride, sulfate, total nitrogen, and TOC to evaluate water quality conditions for favorability of natural attenuation of perchlorate. Chloride was detected at a concentration of 43 mg/L (Table 2). Sulfate was detected at a concentration of 12 mg/L. Total nitrogen was not detected above the limit of quantitation. Total organic carbon was detected at a concentration of 15 mg/L (Table 2). The detected concentrations of the common anions chloride and sulfate fall well below the established groundwater BTVs of 803 and 376, mg/L, respectively (MWH, 2009). No groundwater BTV has been established for total nitrogen or TOC. No Primary MCLs have been established for common anions and TOC.

3.1.5 Total Petroleum Hydrocarbons, VOCs, and SVOCs

TPHe, diesel-range TPH (TPHd) and heavy hydrocarbon-range TPH (TPHmo) were not detected in the groundwater sample collected from well EOD-MW-1 (Table 2). Diesel-range TPHd and TPHmo were last detected in groundwater collected from the site in 2012 at concentrations close to the detection limit (Table 7). The value for the TPHe reporting level for this sampling event was qualified as estimated (Table 6). The project chemist applied this qualifier because the sample holding time was exceeded by one day. In accordance with EPA guidance in Contract Laboratory Program National Functional Guidelines (NFG) for Organic Data Review, EPA 540/R-94/012, February 1994, if technical holding times are exceeded, sample quantitation limits are qualified "UJ," which represents not detected and the quantitation limit is estimated. The project chemist can elect to reject the sample results for gross holding time exceedances as determined by the project chemist's professional judgement. Typically, rejecting data for gross holding time exceedance occurs when the holding time is twice or more the method holding time. In this case, the laboratory held the sample too long and exceeded the method holding time. Due to the analytical time exceedance, the project chemist elected to run VOC and SVOC analysis to remain consistent with the intent of the SAP requirements.

Two VOCs, 1,4-dichlorobenzene and acetone, were detected below their level of quantitation, and their estimated concentration values are below their respective RSLs for tap water and the California MCL for 1,4-dichlorobenzene. No SVOC analytes were detected; however, the results for the SVOC analytes were also qualified UJ due to sample holding time exceedance of one day (Table 3). In this case, the project chemist elected not to reject the SVOC results as they did not grossly exceed the holding time. The sample holding time exceedance was caused by the holding time exceedance for the TPHe analysis.

3.2 Soil

3.2.1 Metals

3.2.1.1 Metals in Surface Soil

Antimony, arsenic, lead, and silver were detected at concentrations above their respective surface alluvium BTV in one or more of the MI surface soil samples and in the replicate sample collected from the DUs (Table 4 and Figure 3).

Antimony was detected at a concentration of 1.66 mg/kg in the MI sample collected from EOD-DU1. Arsenic was detected in samples collected from EOD-B4 and EOD-B6 at 9.35 and 9.49 mg/kg, respectively. Lead was detected at an estimated concentration of 45 mg/kg, 19.9 mg/kg, and 12.7 mg/kg respectively in EOD-DU1, EOD-DU2, and EOD-DU3. Silver was detected in all of the DUs with estimated concentrations ranging from 0.566 to 3.64 mg/kg.

The concentrations of all other metals detected in MI surface soil samples were less than their applicable surface alluvium BTVs (Table 4).

3.2.1.2 Metals in Subsurface Soil

Antimony was detected in the discrete subsurface soil sample collected from EOD-B2 (1.95 mg/kg) at a concentration greater than the BTV of 1.1 mg/kg.

Arsenic was detected in the discrete subsurface soil samples collected from EOD-B4 (estimated at 9.35 mg/kg) and EOD-B6 (estimated at 9.49 mg/kg) at a concentration greater than the BTV of 8.9 mg/kg.

Lead was detected in the discrete subsurface soil sample collected from EOD-B2 (estimated at 25.1 mg/kg) at a concentration greater than the BTV of 11 mg/kg.

No metals were detected at concentrations above BTVs in the discrete subsurface soil samples from locations EOD-B1, EOD-B3, EOD-B5, EOD-B7, EOD-B8, EOD-B9 (and duplicate EOD-B11), and EOD-B10. The concentrations of lead observed in samples collected for the 2015 assessment are consistent with historical data (Table 7). The concentrations of metals detected at concentrations below BTVs were also consistent with historical data.

3.2.2 Explosives

Multi-increment surface soil samples collected from the DUs and discrete subsurface soil samples collected from locations EOD-B1 through EOD-B10 were analyzed for explosives (Table 5).

3.2.2.1 Explosives in Surface Soil

One explosive analyte, HMX, was detected in the EOD-DU1 surface soil MIS sample at 0.291 mg/kg (Table 5). This value is commensurate with previous detections (Table 7) and is well below its RSL for industrial soil of 57,000 mg/kg.

3.2.2.2 Explosives in Subsurface Soil

No explosives were detected in subsurface soil samples collected from EOD-B1 through EOD-B10. Previously, 2.4.6-TNT was detected in 2010 at EOD-B4, and HMX was detected in 2012 at EOD-B4 at concentrations of 0.0184 and 0.0078 mg/kg, respectively (Table 7). These concentrations are well below their RSLs. No other detections of explosives in subsurface soil are indicated since 2009.

3.2.3 Perchlorate

Perchlorate was detected in all surface soil MIS samples and seven of the eleven subsurface soil samples collected for the 2015 EOD Range Assessment (Table 5, Figure 3). The concentrations of perchlorate ranged from an estimated concentration of 11 micrograms per kilogram (μg/kg) in EOD-DU4 to 1,500 μg/kg at EOD-B1. All detected concentrations of perchlorate were orders of magnitude below the RSL for industrial soil of 720,000 μg/kg and the industrial CHHSL of 350,000 μg/kg. Perchlorate concentrations generally diminished with distance away from the EOD Range detonation area and the samples collected from upwind of the detonation area (EOD-DU4) were of lower concentration than comparable downwind samples.

3.2.4 Total Petroleum Hydrocarbons

Soil sampling from truck bomb locations for TPHd analysis were all non-detect (Table 6).

TPHmo testing resulting in detections at discrete sample locations EOD-TB-2 (surface, 25 mg/kg and subsurface, 24 mg/kg), EOD-TB-3 (surface, 15 mg/kg), EOD-TB-4 (surface, 17 mg/kg), EOD-TB-5 (surface, 73 mg/kg), and EOD-TB-6 (surface, 28 mg/kg). These concentrations are similar to previous TPHmo detections at the truck bomb locations and are all below the level at which additional analyses are required (2008 SAP).

3.2.5 Volatile and Semivolatile Organic Compounds

Soil sampling from truck bomb locations for VOCs and SVOCs were not analyzed due to TPHe results being below 1000 mg/kg (as per the 2008 SAP).

3.3 Results Summary

3.3.1 Groundwater

As shown in Table 1, three metals and one metalloid (arsenic) were detected in groundwater at the site above BTVs, MCLs, or RSLs, as follows:

1. Iron was detected in the filtered groundwater sample at an estimated concentration of 11,800 µg/L in sample EOD-MW-1-1215 compared to a BTV of 3,530 µg/L. Iron was detected in the unfiltered sample at an estimated concentration of 11,800 µg/L in sample EOD-MW-1-1215.

2. Chromium was detected in the filtered sample at a concentration of 17 µg/L in sample EOD-MW-1-1215 which is greater than the BTV of 12 µg/L. Chromium was detected in the unfiltered sample at a concentration of 16.8 µg/L in sample EOD-MW-1-1215.

3. Aluminum was detected in the filtered sample at an estimated value of 10,300 micrograms per liter (µg/L) in sample EOD-MW-1-1215, which is greater than the BTV of 1,200 µg/L. Aluminum was detected in the unfiltered sample at an estimated value of 10,400 micrograms per liter (µg/L) in sample EOD-MW-1-1215.

4. Arsenic was detected in the filtered groundwater sample at an estimated concentration of 5.22 µg/L in sample EOD-MW-1-1215 which is above the RSL of 0.045 µg/L (Table 1).

EOD Range Assessments performed in 2010 and 2012 detected dissolved iron above the BTV in the filtered groundwater sample at concentrations of 3,970 and 4,850 µg/L, respectively (Tetra Tech 2010 and 2013). The concentration of dissolved iron in filtered groundwater during this sampling event was 11,800 µg/L.

The concentration of lead detected in filtered groundwater previously exceeded the BTV in 2009 and 2012 at concentrations of 3.2 and 8.3 µg/L, respectively. Lead was not detected in the sample collected for this sampling event (Tables 1 and 7). No other metals have been historically detected in groundwater samples at concentrations greater than BTVs (Table 7).

Explosives and perchlorate were not detected in groundwater during the 2015 EOD Range Assessment. Explosives have never been detected in EOD Range groundwater samples. Perchlorate was detected in 2010 and 2012 at concentrations ranging between 0.281 and 73 µg/L (Table 7).

TPHe was not detected in groundwater during this investigation; however, due to the sample being analyzed one day out of holding time, the groundwater samples were also analyzed for VOCs or SVOCs to be conservative and to ensure compliance with the approved SAP. Only two VOCs were detected: 1,4-dichlorobenzene and acetone. Both of these results were qualified as estimated concentrations due to the holding time discrepancy; however, neither were detected at concentrations above their respective RSLs for tap water, and 1,4-dichlorobenzene was not detected above its California MCL.

Chloride and sulfate (Table 2) were detected in the unfiltered groundwater sample (43 and 12 mg/L, respectively) at concentrations significantly lower than their 95th percentile BTVs. Field measurements indicated low DO in the perched aquifer, a condition favorable for reducing bacteria responsible for perchlorate degradation. Relatively low concentrations of sulfate and total nitrate as well as a sufficient source of TOC further favor natural perchlorate degradation in site groundwater because reducing bacteria will utilize perchlorate as an electron acceptor for metabolism in the absence of these alternate electron acceptors in the presence of sufficient TOC as an electron source. The field measurements for pH and ORP were at the limit of the optimal range for reducing bacteria to utilize perchlorate as an electron acceptor for their metabolism (Table 8).

3.3.2 Soils

3.3.2.1 Metals in Soil

Four metals were detected above BTVs in MI surface soil samples and discrete subsurface soil samples collected from EOD Range Assessment DUs:

1. Antimony was detected above its BTV of 1.1 mg/kg in the discrete subsurface sample at EOD-B2 and in the MI surface sample at EOD-DU1 (1.95 and 1.66 mg/kg, respectively).

2. Arsenic was detected above its BTV of 8.9 mg/kg in discrete subsurface samples from EOD-B4 and EOD-B6 (9.35 and 9.49 mg/kg, respectively).

3. Lead was detected above its BTV of 12 for surface soil alluvium at EOD-DU1, EOD-DU2, and EOD-DU3, ranging up to 19.9 mg/kg; lead was also detected above its BTV of 11 for subsurface soil at EOD-B2 at a concentration of 25.1 mg/kg.

4. Silver was detected above its BTV of BTV of 0.2 for surface alluvium at EOD-DU1, EOD-DU2, EOD-DU3, and EOD-DU4, and in the replicate MI sample collected from EOD-DU4 (EOD-DU5).

Antimony was detected at similar concentrations in 2012 and 2014 at locations EOD-DU1 and EOD-DU2 (Table 7). H

Arsenic was previously detected at 16.1 mg/kg at EOD-B4 in 2010. Three other detections of arsenic of up to 20.1 mg/kg were detected at EOD-B7 and EOD-B8 in 2009 with one detection of 18.5 mg/kg observed at EOD-B7 in 2012 (Table 7). Arsenic is typically associated with chemical agents, and not with explosive ordnance (Albright 2012) and would not be expected to be associated with detonation at this site.

Lead has generally been detected above its BTV for surface soil in EOD-DU1, EOD-DU2, and EOD-DU3with concentrations decreasing in direct correlation with distance downwind of the detonation area (EOD-DU1). Since 2009, lead has not exceeded the BTV in in any of the upwind MI surface soil samples collected in EOD-DU4. In subsurface soil, lead has exceeded its BTV only three times prior to 2015, 19.5 and 21.6 mg/kg at EOD-B3 in 2013 and 2014, respectively, and 17.2 mg/kg at EOD-B4 in 2012.

Silver has been intermittently detected in the upwind decision unit (EOD-DU4) at concentrations greater than the BTV (Table 7). No other metals have been detected at concentration greater than the BTV in the MI surface soil sample in EOD-DU4, upwind of the detonation area (Table 7, Figure 3).

3.3.2.2 Explosives and Perchlorate in Soil

One explosive, HMX, was detected in surface soil at EOD-DU1, which is within the detonation area, at a concentration of 0.291 mg/kg. RSL for HMX is 49,000 mg/kg.

Perchlorate was detected in all MI surface soil samples ranging from 11 mg/kg at EOD-DU4 to 1,200 mg/kg at EOD-DU1, and as shown in Table 5, all of the perchlorate results for the MI surface soil samples were

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estimated. For values above the reporting limit, the "J" qualifier was applied due to elevated recoveries in quality control samples, specifically the matrix spike and matrix spike duplicate samples. These perchlorate concentrations were orders of magnitude below the RSL for industrial soil of 720,000 μg/kg and the industrial CHHSL of 350,000 μg/kg and were detected in a similar range of concentrations as in previous investigations (Table 7). Perchlorate concentrations in MI surface soil samples were greatest in the EOD detonation area EOD-DU1 (Figure 3). Concentrations of perchlorate generally declined with increasing distance downwind from the detonation area and were lowest in the sample collected upwind of the detonation area, EOD-DU4.

Perchlorate was also detected in 7 of 11 subsurface soil samples collected for the 2015 EOD Range Assessment (Table 5, Figure 3). The concentrations of perchlorate ranged up to 1,500 μg/kg at EOD-B1. All detected concentrations of perchlorate in subsurface soil were orders of magnitude below the RSL for industrial soil of 720,000 μg/kg and the industrial CHHSL of 350,000 μg/kg. Perchlorate concentrations generally declined with increasing distance downwind from the detonation area and were not detected in the sample collected from boring EOD-B10 upwind of the detonation area.

4.0 INVESTIGATION DERIVED WASTE

Purge water from monitoring well EOD-MW-1 and all decontamination water were stored in the contractor support trailer at Vandenberg AFB in labeled 5-gallon F-style polyethylene jugs with screw caps and were disposed of at the Vandenberg AFB Industrial Wastewater Treatment Plant evaporation ponds. Soil cuttings from the hand auger borings were placed back in the boreholes after sampling was completed per the SAP (Tetra Tech 2008). Used personal protective equipment (PPE) was decontaminated and disposed of as municipal waste in accordance with the SAP (Tetra Tech 2008). PPE was washed with Alconox and potable water to remove all visible contamination and then rinsed with potable water prior to disposal.

No other investigation derived waste was generated during this investigation.

5.0 CONCLUSIONS

No hazardous levels of PEP compounds (explosives or perchlorate) or metals were detected in any samples collected during this investigation.

Aluminum was detected in both the filtered and unfiltered groundwater samples (10,300 and 10,400 μg/L, respectively) at a concentrations above the California Primary MCL of 1,000 μg/L. Aluminum was detected above the MCL in 2011, 2012, 2013, and 2014 at concentrations ranging up to 21,700 (in 2012). Arsenic was detected in the unfiltered groundwater sample at a concentration of 6.74 μg/L, above the RSL for tap water of 0.052 μg/L. Arsenic was previously detected in 2009 in filtered and unfiltered groundwater and in 2014, in filtered groundwater at concentrations above the RSL for tap water and the California Primary MCL of 10 μg/L (Table 7).

TPHd, TPHmo, and TPHe (total of TPHd and TPHmo), were not detected in the groundwater samples collected from well EOD-MW-1 (Table 2). Due to a laboratory error that caused the samples for TPHe to exceed their holding time by one day, the groundwater samples were also analyzed for VOCs and SVOCs. Only the VOCs 1,4-dichlorobenzene and acetone were detected, and both were at concentrations below their respective RSL for tap water and California Primary MCL. Considering that the detection of TPHmo and TPHd observed in 2014 was considered to be cross contamination as qualified by a laboratory blank, TPHd and TPHmo were last detected in groundwater collected from the site in 2012. TPHe were detected at similar concentrations only intermittently since 2009 suggesting there is no significant threat to perched groundwater from previous uses of ANFO explosives at the site (Table 7). Use of ANFO has been discontinued at the EOD range.

No explosives were detected in groundwater samples collected for the 2015 annual range assessment.

The perchlorate groundwater sample result from the 2015 assessment again highlights the hypothesis that perchlorate is not persistent in groundwater at the site; it was not detected in the sample collected on 15 December 2015. The concentration of perchlorate in groundwater has been observed during previous sampling rounds to rapidly decline in groundwater (from 73 µg/L on 19 April 2011 to 12 µg/L on 29 June 2011). These fluctuations in concentration may be related to the combination of seasonal rainfall patterns and the restricted nature of the isolated perched groundwater at the site. Certain groundwater geochemistry conditions have also been shown to promote naturally occurring anaerobic bacteria populations responsible for perchlorate degradation (ITRC 2008). Favorable geochemistry includes a pH between 6.5 and 7.5, ORP values between 0 and –100 mV, and low DO concentrations. Historical perchlorate sample results appear to show that any perchlorate that reaches perched groundwater degrades naturally after the end of seasonal rainfall (Table 7). Groundwater at the site is contained in an isolated perched zone with little or no recharge other than infiltration; therefore, once infiltrated meteoric water in the perched groundwater zone is depleted of oxygen by aerobic processes, the resulting reducing conditions persist until the next wet season (Table 8). Groundwater parameters from field measurements on 15 December 2015 were slightly outside of the ranges for pH and ORP, but are optimal for DO (Table 8). The low observed concentrations of sulfate and total nitrogen also show that groundwater conditions support perchlorate degradation since low concentrations of these anions force reducing bacteria to seek alternate electron acceptors for their metabolism. A matching source of electron donor from TOC at concentrations greater than 6 mg/L is also necessary to support perchlorate degradation (ESTPC 2010). Groundwater sample results for TOC of 15 mg/L indicate that an adequate source is likely available (Table 2).

Current and historic field parameter measurements of DO suggest that groundwater conditions at EOD-MW-1 are more conducive to perchlorate degradation after the end of seasonal rainfall (Table 8). Therefore, perchlorate transported to the isolated groundwater body at EOD-MW-1 during the rainy season appears to be quickly degraded by biological action as favorable groundwater conditions for biodegradation appear to develop in the aquifer. It appears that these reducing conditions become established within a relatively short period after the end of seasonal rainfall, as evidenced from the optimally low DO concentrations documented during June and July in 2009, 2010, and 2011. Most sampling rounds have been performed after rainfall had ended for the season; except for 2011, where sampling in April occurred following heavy seasonal rainfall in February and March. These low DO conditions then appear to persist until significant seasonal rainfall occurs, as evidenced by the parameters measured in 2012 and 2013, when sampling was performed in the fall before the onset of seasonal rainfall (Table 8). In December 2015, seasonal rainfall had already occurred in two events before sampling commenced totally only 4.56 inches, as observed at the Base weather office. The historic low water level observed in well EOD-MW-1 suggest low rainfall amounts have not significantly recharged the perched groundwater zone (Table 8). Concentrations of perchlorate will continue to be monitored during future sampling events to determine if this pattern persists.

Antimony, arsenic, lead, and silver were detected in soil samples at concentrations that exceed the respective BTVs for surface or subsurface alluvium. The concentrations generally decline with distance downwind of the detonation area. Silver was only detected at concentrations greater than its BTV in samples collected from the detonation area, EOD-DU1. The detected concentrations of metals are consistent with previous assessment results.

Explosives residues and perchlorate were not present at concentrations exceeding the RSLs in any soil samples collected during this assessment. The detected concentrations range between two and six orders of magnitude lower than the RSLs and the perchlorate CHHSL.

Based on the data obtained during this investigation, EOD Flight ordnance disposal practices appear to adequately dispose of the PEP compounds and have not resulted in the presence of explosives residues or perchlorate at concentrations that exceed the RSLs for industrial soil. TPHe were only sporadically detected in soil at concentrations greater than the screening level before permanent discontinuation of truck bomb training events. Petroleum hydrocarbons have been removed from the waste stream at the EOD Range with the permanent discontinuation of the truck bomb training event. Furthermore, TPHe were previously detected in site groundwater samples at much less than the project action level of 1 mg/L. Perchlorate was not detected in groundwater during this annual sampling round; however, perchlorate will continue to be monitored during future sampling rounds.

6.0 RECOMMENDATIONS

The Engineering Value Analysis performed as an essential part of this report (Appendix F) recommends that the EOD Range Assessment continue to be conducted in accordance with the SAP (Tetra Tech 2008). If the Air Force should choose to revise the SAP if renewal of the RCRA Part B Permit occurs in 2018, the following revisions should be implemented to optimize the sampling program:

- Discontinue collecting surface soil for VOC and SVOC analysis. There are no identified sources for VOCs and SVOCs in the EOD Range waste stream.

- Discontinue discrete soil sample collection and TPH analysis for truck bomb training events because use of ammonium nitrate and fuel oil (ANFO) explosives has been permanently discontinued at the EOD Range. Before discontinuation, TPHe were only sporadically detected in site soil samples.

- Discontinue groundwater sample analysis for potential VOCs and SVOCs because data from the last seven sampling events (2009 through 2015) have not indicated the presence of TPH at concentrations close to the project screening level of 1 mg/L and there are no identified sources for these compounds in the EOD Range waste stream.

- Discontinue groundwater sample analysis for TPH because ANFO, the source for potential TPH groundwater contamination, has been removed from the EOD Range waste stream.

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